PATENT COOPERATION TREATY

From the INTERNATIONAL BUREAU

PCT

NOTIFICATION OF THE RECORDING OF A CHANGE

(PCT Rule 92bis.1 and Administrative Instructions, Section 422)

To:

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Date of mailing (day/month/year)
31 January 2002 (31.01.02)

Applicant's or agent's file reference
91727/JPR

IMPORTANT NOTIFICATION

International application No.
PCT/EP99/06719

International filing date (day/month/year)
09 September 1999 (09.09.99)

1. The following indications appeared on record concerning:

[X] the applicant [ ] the inventor [ ] the agent [ ] the common representative

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2. The International Bureau hereby notifies the applicant that the following change has been recorded concerning:

[ ] the person [X] the name [ ] the address [ ] the nationality [ ] the residence

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3. Further observations, if necessary:

4. A copy of this notification has been sent to:

[X] the receiving Office
[ ] the International Searching Authority
[X] the International Preliminary Examining Authority
[ ] the designated Offices concerned
[X] the elected Offices concerned
[ ] other:

The International Bureau of WIPO
34, chemin des Colombettes
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PATENT COOPERATION TREATY

From the INTERNATIONAL BUREAU

PCT

NOTIFICATION OF ELECTION

(PCT Rule 61.2)

To:

Commissioner
US Department of Commerce
United States Patent and Trademark
Office, PCT
2011 South Clark Place Room
CP2/5C24
Arlington, VA 22202
ETATS-UNIS D'AMERIQUE

in its capacity as elected Office

Date of mailing: 15 March 2001 (15.03.01)	
International application No.: PCT/EP99/06719	Applicant's or agent's file reference: 91727/JPR
International filing date: 09 September 1999 (09.09.99)	Priority date:
Applicant: HORNEMAN, Kari et al	

1. The designated Office is hereby notified of its election made:

[X] in the demand filed with the International preliminary Examining Authority on:

08 January 2001 (08.01.01)

[ ] in a notice effecting later election filed with the International Bureau on:

2. The election [X] was

[ ] was not

made before the expiration of 19 months from the priority date or, where Rule 32 applies, within the time limit under Rule 32.2(b).

The International Bureau of WIPO 34, chemin des Colombettes 1211 Geneva 20, Switzerland	Authorized officer: J. Zahra
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PATENT COOPERATION TREATY

REC'D 11 DEC 2001
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INTERNATIONAL PRELIMINARY EXAMINATION REPORT

(PCT Article 36 and Rule 70) / 2

Applicant's or agent's file reference	FOR FURTHER ACTION	See Notification of Transmittal of International Preliminary Examination Report (Form PCT/IPEA/416)
91727/JPR		
International application No.	International filing date *(day/month/year)*	Priority date *(day/month/year)*
PCT/EP99/06719	09/09/1999	
International Patent Classification (IPC) or national classification and IPC		
H04L25/02		
Applicant		
NOKIA NETWORKS OY et al.		

1. This international preliminary examination report has been prepared by this International Preliminary Examining Authority and is transmitted to the applicant according to Article 36.

2. This REPORT consists of a total of 5 sheets, including this cover sheet.

   ☒ This report is also accompanied by ANNEXES, i.e. sheets of the description, claims and/or drawings which have been amended and are the basis for this report and/or sheets containing rectifications made before this Authority (see Rule 70.16 and Section 607 of the Administrative Instructions under the PCT).

   These annexes consist of a total of 1 sheets.

3. This report contains indications relating to the following items:

   - I ☒ Basis of the report
   - II ☐ Priority
   - III ☐ Non-establishment of opinion with regard to novelty, inventive step and industrial applicability
   - IV ☐ Lack of unity of invention
   - V ☒ Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations suporting such statement
   - VI ☐ Certain documents cited
   - VII ☒ Certain defects in the international application
   - VIII ☐ Certain observations on the international application

Date of submission of the demand	Date of completion of this report
08/01/2001	07.12.2001
Name and mailing address of the international preliminary examining authority: European Patent Office D-80298 Munich Tel. +49 89 2399 - 0 Tx: 523656 epmu d Fax: +49 89 2399 - 4465	Authorized officer Pajatakis, E Telephone No. +49 89 2399 8898

Form PCT/IPEA/409 (cover sheet) (January 1994)

INTERNATIONAL PRELIMINARY EXAMINATION REPORT

International application No. PCT/EP99/06719

I. Basis of the report

1. With regard to the **elements** of the international application *(Replacement sheets which have been furnished to the receiving Office in response to an invitation under Article 14 are referred to in this report as "originally filed" and are not annexed to this report since they do not contain amendments (Rules 70.16 and 70.17))*:
Description, pages:

1-23	as originally filed	

Claims, No.:

6 (part),7-24	as originally filed	
1-5,6 (part)	with telefax of	23/11/2001

Drawings, sheets:

1/4-4/4	as originally filed	

2. With regard to the **language**, all the elements marked above were available or furnished to this Authority in the language in which the international application was filed, unless otherwise indicated under this item.

   These elements were available or furnished to this Authority in the following language: , which is:

   - ☐ the language of a translation furnished for the purposes of the international search (under Rule 23.1(b)).
   - ☐ the language of publication of the international application (under Rule 48.3(b)).
   - ☐ the language of a translation furnished for the purposes of international preliminary examination (under Rule 55.2 and/or 55.3).

3. With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application, the international preliminary examination was carried out on the basis of the sequence listing:

   - ☐ contained in the international application in written form.
   - ☐ filed together with the international application in computer readable form.
   - ☐ furnished subsequently to this Authority in written form.
   - ☐ furnished subsequently to this Authority in computer readable form.
   - ☐ The statement that the subsequently furnished written sequence listing does not go beyond the disclosure in the international application as filed has been furnished.
   - ☐ The statement that the information recorded in computer readable form is identical to the written sequence listing has been furnished.

4. The amendments have resulted in the cancellation of:

- ☐ the description, pages:
- ☐ the claims, Nos.:
- ☐ the drawings, sheets:

5. ☐ This report has been established as if (some of) the amendments had not been made, since they have been considered to go beyond the disclosure as filed (Rule 70.2(c)):

   (Any replacement sheet containing such amendments must be referred to under item 1 and annexed to this report.)

6. Additional observations, if necessary:

V. Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

1. Statement

Novelty (N)	Yes:	Claims	3-5,7-9,11,15,17,18,22
	No:	Claims	1,2,6,10,12-14,16,19-21,23,24
Inventive step (IS)	Yes:	Claims	
	No:	Claims	1-24
Industrial applicability (IA)	Yes:	Claims	1-24
	No:	Claims	

2. Citations and explanations
   see separate sheet

VII. Certain defects in the international application

The following defects in the form or contents of the international application have been noted:
see separate sheet

Re Item V

Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

1. The subject-matter of Claim 1 is not new, Article 33(2).

   D1 = GB-A-2 301 999 discloses a method for estimating data transmission rate in a communication system with variable data transmission rates wherein a transmission signal includes a plurality of data symbols over a sequence of data frames (page 1, paragraphs 1-3). The method comprises classifying a data frame of a received transmission signal in accordance with a predefined classification of the data transmission rates and estimating the data transmission rate of the received data frame on basis of the classification (page 1, paragraph 3, page 11, paragraphs, 2 and 3, page 12, paragraph 3, page 13, paragraph 1, fig. 3).

2. According to the Applicant the application differs from **D1** in that it relates to variable symbol rates. It is not agreed with this opinion because variable symbol rates are not mentioned in Claim 1. Claim 1 only mentions variable data rates. This clearly includes the case of variable bit rates which is disclosed in **D1** (see also paragraph spanning pages 3 and 4). Further, the description does not offer any basis for limiting the claims to variable symbol rates.

   The Applicant also mentioned that **D1** does not disclose using the spectral density of the received signal. This feature is, however, not mentioned in Claim 1.

3. The above finding also applies to Claim 19 which corresponds to Claim 1.

4. The additional features of the dependent claims do not add anything new or inventive to the above-mentioned independent claims because these features are either known from the above prior art (classification based on frequency content, calculation of spectral density, indication of high frequencies, CDMA) or common measures (Fast Fourier Transform, noise removal, channel estimation).

Re Item VII

Certain defects in the international application

1. The claims do not contain reference signs in parentheses, Rule 6.2(b).

3. **D1** is not mentioned in the description and the description is not adapted to the wording of the independent claims, Rule 5.1(a)(ii)(iii).

CLAIMS

1. A method for estimating data transmission rate in a communication system with variable data transmission rates wherein a transmission signal includes a plurality of data symbols over a sequence of data frames, comprising:

classifying a data frame of a received transmission signal in accordance with a predefined classification of the data transmission rates; and

estimating the data transmission rate of the received data frame on basis of said classification.

2. A method according to claim 1, wherein the data frames are classified based on frequency content of the received transmission signal.

3. A method according to claim 1 or 2, wherein the data frames are classified based on a power spectral density function estimate of the received transmission signal.

4. A method according to claim 3, wherein the power spectral density function estimate of the received transmission signal is calculated using a Fast Fourier Transform algorithm and coherent averaging of the data symbol sequence of the received transmission signal.

5. A method according to claim 4, wherein a modified Fast Fourier Transform algorithm is used, said modified Fast Fourier Transform algorithm taking predefined symmetries of the transmitted data symbols into account.

6. A method according to any of claims 3 to 5, wherein the estimation of the power spectral density function comprises the steps of:

REPLACED BY ART 34 AMDT

CLAIMS

1. A method for estimating data transmission rate in a communication system with variable data transmission rates wherein a transmission signal includes a plurality of data symbols over a sequence of data frames, comprising:

classifying a data frame of a received transmission signal in accordance with a predefined classification of the data transmission rates; and

estimating the data transmission rate of the received data frame on basis of said classification.

2. A method according to claim 1, wherein the classification is based on frequency content of the received transmission signal.

3. A method according to claim 1 or 2, wherein the classification is based on a power spectral density function estimate of the received transmission signal.

4. A method according to claim 3, wherein the power spectral density function estimate of the received transmission signal is calculated using a Fast Fourier Transform algorithm and coherent averaging of the data symbol sequence of the received transmission signal.

5. A method according to claim 4, wherein a modified Fast Fourier Transform algorithm is used, said modified Fast Fourier Transform algorithm taking predefined symmetries of the transmitted data symbols into account.

6. A method according to any of claims 3 to 5, wherein the estimation of the power spectral density function comprises the steps of:

Preliminary amendment of the US claims

CLAIMS

1. A method for estimating data transmission rate in a communication system with variable data transmission rates wherein a transmission signal includes a plurality of data symbols over a sequence of data frames, comprising:

classifying a data frame of a received transmission signal in accordance with a predefined classification of the data transmission rates; and

estimating the data transmission rate of the received data frame on basis of said classification.

2. A method according to claim 1, wherein the data frames are classified based on frequency content of the received transmission signal.

3. A method according to claim 1, wherein the data frames are classified based on a power spectral density function estimate of the received transmission signal.

4. A method according to claim 3, wherein the power spectral density function estimate of the received transmission signal is calculated using a Fast Fourier Transform algorithm and coherent averaging of the data symbol sequence of the received transmission signal.

5. A method according to claim 4, wherein a modified Fast Fourier Transform algorithm is used, said modified Fast Fourier Transform algorithm taking predefined symmetries of the transmitted data symbols into account.

6. A method according to claim 3, wherein the estimation of the power spectral density function comprises the steps of:

dividing the total number of received data symbols into blocks, wherein each block includes a predefined amount of consecutive points of the signal;

calculating an individual Fourier Transform for each of said blocks for receiving squared real and imaginary points for each frequency of the signal;

calculating an individual power spectral function estimate for each of the blocks by summing the squared real and imaginary points; and

calculating the power spectral density function estimate by averaging the individual power spectral function estimates.

7. A method according to claim 3, wherein the power spectral density function estimate is normalised by summing the elements of the power spectral density function for obtaining a sum of the elements and by dividing each of said elements by the sum.

8. A method according to claim 1, wherein the classification further comprises a step of removing effects of noise.

9. A method according to claim 8, wherein the data frames are classified based on a power spectral density function estimate of the received transmission signal, the noise removal comprising subtracting an inverse of the number of elements of the power spectral density function from the power spectral density function.

10. A method according to claim 3, wherein the classification comprises further:

calculating a variable from the power spectral density function for characterising the frequency content of the power spectral density function; and

comparing the variable against limit values of a classification decision structure.

11. A method according to claim 10, wherein the variable characterising the frequency content of the received transmission signal comprises center-of-moment of the power spectral density function.

12. A method according to claim 10, wherein the magnitude of the variable indicates the relative amount of high frequencies present in the power spectral density function.

13. A method according to claim 1, wherein the communication system comprises a cellular code division multiple access communications network, and the data is transmitted between a mobile station and a base station of the network over a radio interface.

14. A method according to claim 1, wherein the number of data transmission rate classes of the predefined classification equals the number of the possible data transmission rates.

15. A method according to claim 1, wherein the number of data transmission rate classes of the predefined classification is lower than the number of the possible data transmission rates.

16. A method for channel estimation in a cellular code division multiple access communication system wherein a plurality of data symbols is spread over a sequence of data frames in a transmission signal with variable data transmission rates, comprising: :

classifying a data frame of a received transmission signal in accordance with a predefined classification of the

data transmission rates; and

estimating the data transmission rate of the received data frame on basis of said classification.

17. A method according to claim 16, wherein the estimate of the data transmission rate is used to assist in rate selection for Viterbi decoding of the received data symbols.

18. A method according to claim 16, wherein a data rate information received from a transmitting station and the estimated data transmission rate are both used for the channel estimation.

19. Signal receiving circuitry for use in a communication system with variable data transmission rates wherein data is transmitted as a plurality of data symbols over a sequence of data frames, the signal receiving circuitry comprising a rate estimation unit for receiving an incoming transmission signal, for classifying a data frame of the signal in accordance with a predefined classification of the data transmission rates, and for determining from the results of the classification an estimate of the data transmission rate of the received data frame.

20. Signal receiving circuitry according to claim 19, wherein the rate estimation unit estimates the data transmission rate based on the frequency content of the received signal.

21. Signal receiving circuitry according to claim 19, wherein the rate estimation unit is arranged to classify the received signal based on a power spectral density function estimate of the received transmission signal.

22. Signal receiving circuitry according to claim 19,

comprising a channel estimation unit which utilises the estimated data transmission rate of the received signal in channel estimation.

23. A mobile station including signal receiving circuitry arranged for use in communication via a communication system with variable data transmission rates wherein data is transmitted as a plurality of data symbols over a sequence of data frames, the signal receiving circuitry comprising a rate estimation unit for receiving an incoming transmission signal, for classifying a data frame of the signal in accordance with a predefined classification of the data transmission rates, and for determining from the results of the classification an estimate of the data transmission rate of the received data frame.

24. A base station including signal receiving circuitry for use in communication with variable data transmission rates wherein data is transmitted as a plurality of data symbols over a sequence of data frames, the signal receiving circuitry comprising a rate estimation unit for receiving an incoming transmission signal, for classifying a data frame of the signal in accordance with a predefined classification of the data transmission rates, and for determining from the results of the classification an estimate of the data transmission rate of the received data frame. .

Preliminary amendment of the US claims

CLAIMS

1. A method for estimating data transmission rate in a communication system with variable data transmission rates wherein a transmission signal includes a plurality of data symbols over a sequence of data frames, comprising:

classifying a data frame of a received transmission signal in accordance with a predefined classification of the data transmission rates; and

estimating the data transmission rate of the received data frame on basis of said classification.

2. A method according to claim 1, wherein the data frames are classified based on frequency content of the received transmission signal.

3. A method according to claim 1~~ or 2~~, wherein the data frames are classified based on a power spectral density function estimate of the received transmission signal.

4. A method according to claim 3, wherein the power spectral density function estimate of the received transmission signal is calculated using a Fast Fourier Transform algorithm and coherent averaging of the data symbol sequence of the received transmission signal.

5. A method according to claim 4, wherein a modified Fast Fourier Transform algorithm is used, said modified Fast Fourier Transform algorithm taking predefined symmetries of the transmitted data symbols into account.

6. A method according to ~~any of~~ claim~~s~~ 3~~ to 5~~, wherein the estimation of the power spectral density function comprises

the steps of:

dividing the total number of received data symbols into blocks, wherein each block includes a predefined amount of consecutive points of the signal;

calculating an individual Fourier Transform for each of said blocks for receiving squared real and imaginary points for each frequency of the signal;

calculating an individual power spectral function estimate for each of the blocks by summing the squared real and imaginary points; and

calculating the power spectral density function estimate by averaging the individual power spectral function estimates.

7. A method according to ~~any of~~ claim~~s~~ 3 ~~to 6~~, wherein the power spectral density function estimate is normalised by summing the elements of the power spectral density function for obtaining a sum of the elements and by dividing each of said elements by the sum.

8. A method according to claim 1~~any of the preceding claims~~, wherein the classification further comprises a step of removing effects of noise.

9. A method according to claim 8 ~~when taken together with any of claims 3 to 6~~, wherein the data frames are classified based on a power spectral density function estimate of the received transmission signal, ~~wherein~~ the noise removal comprising ~~es~~ subtracting an inverse of the number of elements of the power spectral density function from the power spectral density function.

10. A method according to ~~any of~~ claim~~s~~ 3 ~~to 9~~, wherein the classification comprises further:

calculating a variable from the power spectral density function for characterising the frequency content of the power spectral density function; and

comparing the variable against limit values of a classification decision structure.

11. A method according to claim 10, wherein the variable characterising the frequency content of the received transmission signal comprises center-of-moment of the power spectral density function.

12. A method according to claim 10~~ or 11~~, wherein the magnitude of the variable indicates the relative amount of high frequencies present in the power spectral density function.

13. A method according to claim 1~~any preceding claims~~, wherein the communication system comprises a cellular code division multiple access communications network, and the data is transmitted between a mobile station and a base station of the network over a radio interface.

14. A method according to claim 1~~any preceding claims~~, wherein the number of data transmission rate classes of the predefined classification equals the number of the possible data transmission rates.

15. A method according to claim 1~~any of claims 1 to 13~~, wherein the number of data transmission rate classes of the predefined classification is lower than the number of the possible data transmission rates.

16. A method for channel estimation in a cellular code division multiple access communication system wherein a

plurality of data symbols is spread over a sequence of data frames in a transmission signal with variable data transmission rates, comprising: ~~wherein the data transmission rate is estimated in accordance with any of claims 1 to 15.~~:

classifying a data frame of a received transmission signal in accordance with a predefined classification of the data transmission rates; and

estimating the data transmission rate of the received data frame on basis of said classification.

17. A method according to claim 16, wherein the estimate of the data transmission rate is used to assist in rate selection for Viterbi decoding of the received data symbols.

18. A method according to claim 16 ~~or 17~~, wherein a data rate information received from a transmitting station and the estimated data transmission rate are both used for the channel estimation.

19. Signal receiving circuitry for use in a communication system with variable data transmission rates wherein data is transmitted as a plurality of data symbols over a sequence of data frames, the signal receiving circuitry comprising a rate estimation unit for receiving an incoming transmission signal, for classifying a data frame of the signal in accordance with a predefined classification of the data transmission rates, and for determining from the results of the classification an estimate of the data transmission rate of the received data frame.

20. Signal receiving circuitry according to claim 19, wherein the rate estimation unit estimates the data transmission rate based on the frequency content of the received signal.

21. Signal receiving circuitry according to claim 19 ~~or 20~~, wherein the rate estimation unit is arranged to classify the received signal based on a power spectral density function estimate of the received transmission signal.

22. Signal receiving circuitry according to ~~any of~~ claims 19 ~~to 21~~, comprising a channel estimation unit which utilises the estimated data transmission rate of the received signal in channel estimation.

23. A mobile station including signal receiving circuitry arranged for use in communication via a communication system with variable data transmission rates wherein data is transmitted as a plurality of data symbols over a sequence of data frames, the signal receiving circuitry comprising a rate estimation unit for receiving an incoming transmission signal, for classifying a data frame of the signal in accordance with a predefined classification of the data transmission rates, and for determining from the results of the classification an estimate of the data transmission rate of the received data frame. ~~according to any of claims 19 to 22.~~

24. A base station including signal receiving circuitry for use in communication with variable data transmission rates wherein data is transmitted as a plurality of data symbols over a sequence of data frames, the signal receiving circuitry comprising a rate estimation unit for receiving an incoming transmission signal, for classifying a data frame of the signal in accordance with a predefined classification of the data transmission rates, and for determining from the results of the classification an estimate of the data transmission rate of the received data frame. ~~according to any of claims 19 to 22~~.

DETERMINATION OF DATA RATE, BASED ON POWER SPECTRAL DENSITY ESTIMATES

Field of the invention

The present invention relates to a method and circuitry for estimating data rates of signals transmitted between stations in a communication system, and more particularly, but not explicitly, between stations in a cellular code division multiple access (CDMA) communication system.

Background of the Invention

In a communication system signals can be transmitted with variable data transmission rates wherein data is transmitted as a plurality of data symbols in subsequent data frames. As is known, in a cellular CDMA (Code Division Multiple Access) system data is encoded for transmission by modulating data symbols to be transmitted by a spreading code and a unique scrambling code for each channel. Within each cell of the cellular communication system, scrambling codes are preferably as far as possible orthogonal to allow for a plurality of different mobile stations to communicate with a base station on selectively coded channels. The effect of a spreading code is to spread the frequency band for transmission to a chip rate Tc which is larger than the bit rate T_b. The scrambling code is unique for each mobile station transmitting to a single base station so that the transmission from individual mobile stations can be distinguished at the base station. The spreading codes are also as orthogonal as possible within users. For example, it is possible to set up such a variable-rate connection where the data rate of the information bits, and thus the spreading factor used in the spreading modulation of these bits, varies from radio frame to radio frame (e.g. every 10 ms). The data

rates used in such a connection are not arbitrary, but for each radio frame duration, one of the pre-defined data rates is used. Moreover, every higher data rate is dividable by a lower data rate, the division factor being 2^k for some $k \geq 0$. This specification presents variable-rate connection data rates 32, 64, 128, 256, 512, and 1024 kbps, but it is evident that also other data rates could be used without departing from the basic concept of the variable data rate (or multirate) transmission.

When a signal is transmitted between a base station and a mobile station (either on the uplink or the downlink) of a CDMA system, the signal receiving unit needs to establish from the received signal some information about the communication path along which the signal has travelled. This is referred to herein as "channel estimation" and is usually carried out in a channel estimation unit which generates a channel impulse response. Various techniques are known for channel estimation. The channel impulse response is required in order to properly decode and demodulate incoming data.

The data transmission rate of the received signal can be used in the channel estimation. However, if the data rate of a received radio frame is not known at the time of the detection at the receiver, the information symbols in said radio frame are usually obtained by means of detecting the complex data symbols assuming that the highest-possible data rate is used for transmission, and using the lowest-possible spreading factor in the receiving station. Assuming that the data rate of the received radio frame was 1024 kbps, this corresponds to the spreading factor of 4 (at 4.096 Mcps) used in the detection of the data symbols. The result of this detection should be a data vector of all detected complex

information symbols corresponding to the received radio frame. Thereafter it has to be estimated what was the actual data rate of the signal at the transmitting station during the transmission. For example, this stage might give a decision that the actual data rate in the received radio frame was 256 kbps, not the assumed 1024 kbps. Finally, in accordance with the estimated data rate, as many adjacent symbols as necessary are summed together to get one actual information symbol. In this example, this would lead to summing up every four adjacent symbols to get one actual information symbol. Therefore it would be advantageous to be able to have the actual data rate of the transmission at the time of the detection at the receiver circuitry.

The transmission between the stations may or may not include explicit information of the data rates of the transmitted signal. In the first case, i.e. if the variable-rate connection includes explicit information on the used data rates for each received radio frame, this information is usually given in a separate channel, for example in an DPCCH (Dedicated Physical Control Channel). However, this information is often encoded in such a way that the actual data rate of the received radio frame is not known at the time the data symbols of the radio frame are detected. In addition, it may be necessary to establish another estimate of the data rate, for instance for the purposes of verification and/or correction of the received data rate information. In the latter case, i.e. if the explicit information is not included in the received signal, so called unknown or blind data rate estimation may be used at the receiving station in order to define at the receiver the actual data rate of the received signal.

One prior art proposal for detecting the data rate of the

received signal is based on the power difference of the received bits in the data channel and the control channel. This method is relatively simple as it requires only the average power estimates of the received control symbols and data symbols. However, the disadvantage of the method is that if a very low spreading factor is used in detecting the data symbols (4 in the above example) in the first place noise becomes very dominant in the detection process. This degrades substantially the performance of the data symbol power estimation.

Another prior art method is based on CRC (Cyclic Redundancy Check: an error detection signal) decoding of the received signal. The method is based on a data rate assumption at each decoding stage and a subsequent selection of a data rate which gives a correct CRC word. To give an example, assuming that the possible data rates are 32, 64, 128, 256, 512, and 1024 kbps, a CRC check would be calculated directly for the information symbols of the received radio frame by assuming firstly a data rate of 1024 kbps. The resulting CRC word is stored. Two adjacent received symbols are summed together, assuming a data rate of 512 kbps, and a further CRC check is calculated for these information symbols. The resulting CRC word is stored. The process continues summing two adjacent information symbols together and calculating CRC checks for all these information streams until a lowest-possible data rate is achieved. Thereafter the stored CRC words are verified and such a data rate is selected that corresponds the rate used in the transmitter when a right CRC check was obtained (if such existed at all). A disadvantage of this method is that it is computationally complex: if there are N possible data rates, this requires N consequent CRC decoding processes before a decision of the transmitter data rate can be made. Moreover, the method does not give any data rate if

the algorithm does not give an exactly matching CRC check.

One prior art proposal is based on metrics of Viterbi decoding of the data, assuming (as in the CRC method) a certain data rate at each stage of the decoding process. This method, however, is also computationally complex and uses assumptions which may lead to even more complicated arithmetical operations and/or inaccurate results of the estimation procedure.

An additional disadvantage of the two latter prior art methods is that they delay the final decision of the data rate of the received signal to a stage where some decoding of the data is needed for the first time. This will make the operation difficult for receiver structures that require an estimate of the data transmission rates of the received signals at an earlier stage than decoding. One such receiver comprises an Interference Cancellation (IC) receiver.

Summary of the Invention

It is an aim of the embodiments of the present invention to address one or several of the disadvantages of the prior art data rate estimation and/or to provide a new type of solution for data rate estimation.

According to an aspect of the present invention there is provided a method for estimating data transmission rate in a communication system with variable data transmission rates wherein a transmission signal includes a plurality of data symbols over a sequence of data frames, the method comprising steps of classifying a data frame of a received transmission signal in accordance with a predefined classification of the data transmission rates and estimating the data transmission

rate of the received data frame on basis of said classification.

According to a more specific embodiment, the classification is based on frequency content of the received transmission signal. The classification can be based on a power spectral density function estimate of the received transmission signal. The power spectral density function estimate can be calculated using a Fast Fourier Transform algorithm and coherent averaging of the data symbol sequence of the received transmission signal.

The power spectral density function estimate can also be normalised by summing the elements of the power spectral density function for obtaining a sum of the elements and by dividing each of said elements by the sum.

Effect of noise can be removed by subtracting an inverse of the number of elements of the power spectral density function from the power spectral density function.

The classification can comprise further steps of calculating a variable from the power spectral density function for characterising the frequency content of the power spectral density function, and comparing the variable against limit values of a classification decision structure.

The estimated data transmission rate can be used in channel estimation.

According to another aspect of the present invention there is provided a signal receiving circuitry for use in a communication system with variable data transmission rates wherein data is transmitted as a plurality of data symbols

over a sequence of data frames, the signal receiving circuitry comprising a rate estimation unit for receiving an incoming transmission signal, for classifying a data frame of the signal in accordance with a predefined classification of the data transmission rates, and for determining from the results of the classification an estimate of the data transmission rate of the received data frame.

According to a more specific embodiment, the signal receiving circuitry is included in a mobile station and/or a base station of a cellular communication system.

The embodiments of the present invention provide several advantages. The embodiments of the invention can be used in a situation where no rate information is transmitted. In addition, the embodiments of the invention can be used in a situation where the rate information is transmitted but cannot, for reason or another, be used or detected from the signal during the receiving process. In addition, one possible use is to provide an additional data rate information which can be used e.g. for correction or error check of a rate information detected from the transmitted signal. The estimate of data transmission rate can also be used in other parts of the received signal processing sequence, e.g. in an IC receiver. The possibility for an early detection of the unknown data rate enables use of any such receiver structure which makes use of the data rate information at an early stage. The estimate can also be used to assist in rate selection for Viterbi decoding of the incoming data symbols, or to assist in decision of an alternative transmission rate for decoding if an error check fails. In addition, embodiments of the invention may assist in provision of a system that is less sensitive to SNR (Signal-to-Noise Ratio) fluctuation.

Brief Description of Drawings

For a better understanding of the invention and to show how the same may be carried into effect reference will now be made by way of example to the accompanying drawings in which:

Figure 1 is a block diagram of a mobile communication system;

Figure 2 illustrates a reception circuitry in a station;

Figure 3 illustrates a slot structure for physical channels for a transmission with unknown data rate;

Figure 4 illustrates a blind rate classification algorithm according to one embodiment of the invention; and

Figure 5 is a diagram showing simulated distributions of variables for different data rates.

Description of Preferred Embodiments of the Invention

Figure 1 is a block diagram illustrating a context in which the present invention may be used. That is, a CDMA mobile communication system allows a plurality of mobile stations MS1, MS2, MS3 to communicate with a base (transceiver) station BTS in a common cell via respective channels CH1, CH2, CH3. These channels are distinguished from one another by the use of scrambling codes in a manner which is know *per se*. Figure 2 is a block diagram of a receive circuitry at a base station in a WCDMA system (Wideband CDMA). The receive circuitry of Figure 2 is for use in uplink direction, i.e. for receiving signals from the mobile stations (MS). It is noted that even though the actual receive circuitry implementation in the downlink direction, i.e. at the mobile station, can be somewhat different, the invention is applicable to downlink transmissions as well.

Before describing the exemplifying receiving circuitry of Figure 2 in more detail, a transmit circuitry (not shown) within a transmitting station will be briefly described. Data to be transmitted between a MS and a BTS may be speech data, video data or other data. The data is encoded into a form suitable for transmission at a bit rate T_b which is dependent on the source of the data, as discussed above. The encoded user data is supplied to a frame multiplexer. The user data can also be supplied to a CRC encoder which generates a check sequence (CRC) for each frame of data. Error correction coding and bit interleaving of the frame sequence can be accomplished prior to transmission in a manner known in the art. The error correction is used in order to protect the user data from errors in a radio channel so that e.g. a Viterbi decoder can recover the coded data even if some of the bits are corrupted. For error coding and decoding purposes, tail bits defining the end of each user data sequence can also be added to the end of user data sequence. Bit interleaving spreads burst errors which typically occur in radio channels more evenly in time to allow the decoder to more efficiently correct the errors from the coded data.

A frame multiplexer organises the data for transmission into a frame sequence. Figure 3 illustrates an example of a slot structure for physical channels DPCCH (Dedicated Physical Control Channel) and DPDCH (Dedicated Physical Data Channel) in the frame sequence. The DPCCH part of the frame contains a pilot sequence (PILOT), a possible rate information (RI) sequence (not shown) and a transmission power control (TPC) sequence. The DPDCH part of the frame contains the whole interleaved user data sequence (user bits and possible CRC bits and possible tail bits). Typically, the user data of the DPDCH is divided into frame periods of 10 milliseconds each, and each frame can have a different transmission rate. Thus,

it is possible to multiplex data from different sources into the frame sequence for transmission and to provide different transmission rates in different frames of the frame sequence. In the following exemplifying embodiments the data rate detection is subjected to the DPDCH sequence of the frame.

The frame sequence is supplied to a spreader which receives spreading and scrambling codes from a code generator. The spreading and scrambling codes are generated in accordance with known CDMA techniques and will not be described further herein. The effect of the spreading code is to spread the frequency band for transmission to a chip rate Tc which is larger than the bit rate T_b. As explained, the scrambling code is unique for each mobile station transmitting to a single base station so that the transmission from individual mobile stations can be distinguished at the base station. If M parallel code channels are employed, M data symbols are spread using different codes and then the results are summed together. The spread signal is supplied to a modulator which modulates the signal ready for transmission, for example according to QPSK modulation. In some systems, modulation is carried out prior to spreading. This sequence of events, however, has no impact on the present invention. The spread, modulated signal is supplied to a digital to analogue (D/A) converter and from there to an RF unit which supplies the signal ready for transmission.

The reception side of the uplink connection will now be described with reference to Figure 2. Signals incoming at an antenna 30 are received by an RF unit 28 and supplied to an analogue to digital (A/D) converter 32. It will readily be understood that a signal may arrive at the receiving station having experienced multipaths with differing propagation delays dn. The A/D converter 32 supplies the digital input

signal to a synchronisation unit 34, a channel estimation unit 37 and to each of a number of despreaders 36a, 36b, 36c. The number of despreaders depends on the likely number of paths experienced by the signal from the base station to the mobile station and is thus dependent on the environment. The synchronisation unit 34 handles the synchronisation of the mobile station to the base station BTS after power has been turned on as well as in a handover case. This includes searching for signals which have been transmitted with the unique scrambling code for that mobile station. Thus, the synchronisation unit 34 receives the unique code from the code generator 22. To perform the search function, synchronisation unit utilises the unique code from the code generator 22 and correlates it with the incoming signal until a strong correlation is detected. After the synchronisation procedure is completed, a dedicated traffic channel can be established. An impulse response measurement unit 35 deals with estimation of the propagation delays dn in order to be able to provide each despreader 36a, 36b, 36c with required scrambling code phases Ø. The phase value of the strongest correlation is supplied to the first despreader 36a and the process is continued to supply respective phase values Ø to the remaining despreaders 36b and 36c. Respective code generators within the despreaders 36a to 36c can thus be used to despread the signal in accordance with the determined phase difference and the resulting narrowband signals are supplied to a coherent combiner and demodulator unit 38.

A channel phase estimate from the channel estimation unit 37 is needed for the combining and demodulation process of the data symbols. Furthermore, an estimate of the data rate is needed from a rate estimator 40 in order to be able to decide how many successful data symbols are to be summed together.

The combined demodulated signal is supplied to a bit detection unit (not shown) which makes a soft or hard decision on the received symbols as to the transmitted bits. The detected bit sequence from the bit detection unit is supplied to a deinterleaving unit (not shown) which effectively undoes the action of the interleaver of the transmitter. The deinterleaved signal can be supplied further to a decoder (not shown) which decodes the error correction coded bits back to the sent user bits and possible CRC bits.

It is noted that several alternative circuit structures to the embodiment shown in Figure 2 are possible to implement the embodiments of the present invention. However, it is generally advisable to have the rate estimation carried out as soon as possible in the receiving process so that it does not hold up the data rate estimation for longer than is necessary.

As already briefly mentioned above, the circuit is provided with the rate estimator unit 40 arranged to receive the despread signal from the despreader 36a. The signal from despreader 36a is assumed to be the strongest signal (i.e. that which has come in along the primary path). As shown by the dashed lines between the signals (branches) from the despreaders 36b and 36c, it is also possible to supply information from a plurality of the despreaders to the rate estimator. According to an option (not shown) more than one estimator 40 is provided in the circuitry. If a plurality of estimators is used, each of the estimators may estimate the data rate of a single signal output branch from despreaders 36a to 36c. Two or several signal branches may also be combined prior to estimation in one of the several estimators, e.g. such that the one estimator estimates the strongest signal while a second estimator estimates the two

next strongest paths and so on.

The rate estimator 40 estimates the data transmission rate by examining the structure of the despread data. The following will describe an embodiment for estimating the transmission data rate of subsequent frames by classifying the data rate of a received signal at the estimator 40 into one of predefined categories, whereafter the decision of the actual data rate of the received signal is based on the predefined category.

The classification of the received signal can be accomplished by examining the frequency content of the received signal, e.g. by means of an estimated one-sided Power Spectral Density (PSD) function of the received signal, as is shown in Figure 4. This is based on the realization that an N-point PSD function of the signal can be defined for an N-point complex time domain signal, said function providing information about the frequency content of the signal. A crude estimate of the PSD function for a signal x can be calculated from a Fourier Transform (FT) of the signal x by equation:

$$(1) \quad PSD(x) = Re(FT(x)) * Re(FT(x)) + Im(FT(x)) * Im(FT(x))$$

The PSD function includes N real values, and the relative amplitudes of these values can be translated to the relative amount of different frequencies present in the signal, starting from the frequency $f = 0$ as the first element of the PSD function and spanning a frequency range up to the Nyquist critical frecuency

(2) $f_c = \frac{1}{2T_s}$,

where T_s = symbol time of one received symbol, despread by using a spreading factor of 4. Now, as one 10 ms radio frame includes 16 * 10 * 64 = 10240 such symbols, the symbol time is:

$$T_s = 10 \text{ ms} / 10240 = 0.977 \ \mu s$$

and thus $$f_c = \frac{1}{2 \cdot 0.977 \mu s} = 512 \text{ kHz}.$$

The above corresponds to a data rate of 512 kbps, which means that in this embodiment, i.e. with a sampling rate of 0.977 μs (using a spreading factor of 4) it is not possible to separate data rates over 512 kbps in the PSD function. This is caused by the nature of the Fourier transform algorithm, i.e. two samples for each transmitted symbol are required in the receiver in order to be able to distinguish by a Fourier transform a certain data rate (frequency). Since the data rate 1024 kbps means that a spreading factor of 4 is used in the transmitter, a spreading factor of 2 should then be used in the receiver to get 2 samples of each transmitted data symbol.

In general, having only $f_c = 512$ kHz means that in the highest data rate case the frequencies over 512 kHz are *aliased* to the PSD function, that is, they are mapped somewhere between 0 and 512 kHz. However, this does not have any disadvantageous effect to the embodiment, since it is not necessary to analyze directly the frequency content of the signal (that is, the relative amplitudes of the PSD function). Instead, the aim of this procedure is to interpret

the frequency content of the signal so that a single decision variable for classification purposes is obtained. Examples of the calculations for receiving the variable will be explained later in this specification.

To estimate the PSD of the received 10240 real symbols of one radio frame, it is possible to accomplish the estimation procedure directly by calculating the Fourier transform of all 10240 symbols and to subsequently calculate from the Fourier transform a PSD estimate. This basic PSD method is enough for enabling an implementation of the above method. However, a preferred procedure discussed in the following will yield to even better results.

When the total number of received symbols P = 10240, the P symbols are divided to K blocks of N consecutive points in each block. In this example N = 64, so $K = P / N$ = 160. $N/2$-point FT is then calculated to each block of N real symbols separately. Denoting $M = N / 2$ yields to M (=32) complex values per each FT. The M-point real PSD function estimate can then be calculated to each data block by summing the squared real and imaginary points for each frequency (see equation (1)). Finally, the final PSD function estimate is calculated by averaging these K individual PSD function estimates.

This procedure has been found to reduce the variance of the PSD function estimate by a factor of $\sqrt{K}$ (= 12.65) from the basic PSD method. The latter method is also in most cases computationally more efficient, since the Fourier transforms of the signal are usually calculated with some kind of Fast Fourier transform (FFT) algorithm, and those algorithms are generally $\log_2(N)$-complex. Thus, even though both method can

be used, it is in most cases logarithmically more efficient to use several short FFTs than to use one long FT.

Computationally, the biggest burden of the above method lies in calculating the 32-point complex Fourier transform to the 64 real symbols of a certain block. However, the complexity of the algorithm can be significantly reduced by using a clever FFT algorithm, preferably one that has been especially modified to take into account certain symmetries concerning the FTs of real data. Such algorithms are per se known, and are thus not discussed in more detail herein.

In pseudo-code representation, the estimation of the PSD function can be written now as:

```
divide input data to K blocks, N consecutive data
symbols in each block;
M = N / 2;
for i := 1 to K
     x := all N real data symbols belonging block i;
     /* The M = N / 2 real points of the FFT are
     returned to fx, and the imaginary points to fy */
     FFT_REAL(x, N, fx, fy);
     for j := 1 to M
          psd(j):=psd(j)+[fx(j)*fx(j)+fy(j)*fy(j)];
     end for j
end for i
divide all elements of psd() by K;
```

After the K M-point PSD functions have been averaged to one M-point PSD function estimate, it may be advantageous to normalise the estimate so that the total power of the PSD function is 1. The normalisation is done by summing all the M

elements of the *psd*() and dividing all elements by this sum. By means of this the sum of the elements of the PSD function, called as PSD *bins*, is 1.

When considering Additive White Gaussian Noise (AWGN) of the signal, one of its properties is that it is white, i.e. non-selective. In other words, the noise extends equally to all frequencies. From the point of view of the PSD function, this would mean that the PSD function of the AWGN would be just a flat line with the value of each bin = $1/M$. For a signal of distinct frequencies of $0...f_c$ plus the AWGN noise in the signal, the PSD function would thus show a bias of $1/M$, and for the distinct frequencies the corresponding bin of the PSD function would be greater than $1/M$. Since the proposed estimation method is only interested of the frequencies whose relative amount in the PSD function exceeds the noise, $1/M$ can be subtracted from the PSD function and all possible resulting negative bins can be reset to zero.

In pseudo-code representation, the normalisation and bias removal operations can be written as

```
NORMALISE(psd, M);
for i := 1 to M
    psd(i) := psd(i) - 1 / M;
    if psd(i) < 0
        psd(i) := 0;
    end if
end for i
```

Before the actual classification of the incoming signal, a final data rate decision variable has to be calculated. As mentioned above, the shape of the PSD function gives

information about its frequency content. It has been realized that for a transmission of lower data rates, e.g. 32 kbps, the PSD function of the received signal is concentrated more to the lower bins, whereas for a transmission of higher data rates, e.g. 1024 kbps, much higher frequencies are present in the signal. Thus the relative amount of the higher bins present in the PSD function has to be bigger. In order to be able to utilize this realization, a variable characterising the frequency content of the PSD function is calculated. A possible variable for this is so called center-of-moment (CM) of the PSD function:

$$\text{CM} = \frac{\sum_{i=1}^{M} i \cdot psd(i)}{\sum_{i=1}^{M} psd(i)} \quad (3)$$

The meaning of the CM variable is as follows: the bigger the CM, the bigger the relative amount of the higher frequencies that are present in the PSD function, and thus it is more probable that the transmitter bit rate was relatively high.

The above algorithm has been tested by extensive simulations accomplished by a MATLAB simulation software provided by *The MathWorks Inc.* The distributions of the PSD center-of-moment variable for various transmission data rates are illustrated in Figure 5 by a histogram in which the horizontal axis defines the number of the PSD bins and the vertical axis defines the number of events. The number of events axis could also be presented in the normalised form, i.e. 0 to 1 instead of the range from 0 to 2200. The distribution curves for different data rates are from left to right: 32, 64, 128, 256, 512, and 1024 kbps. As can be seen from Figure 5, the higher data or bit rates (256 and above) are very clearly

distinguished from each other, which leads to a reliable detection of the higher bit rates.

It is possible to define the distribution of the CM variables for all used (and thus possible) transmitter data rates (32, 64, 128, 256, 512, and 1024 kbps in the example). Based on the predefined distributions, it is then possible to set classification limits for the actual data rate decision. The transmitter data rate estimate can thus be provided by means of the CM variable calculation, followed by a classification of the variable in accordance with a predefined classification rules, e.g. by an estimation structure making use of the predefined classification limits. The actual data rate can then be defined directly from the class.

One possible decision structure for the final estimation is shown below in pseudo-code representation, wherein *sf* = estimate of the spreading factor used in the transmitter:

```
CALC_CM(psd, M, cm);
if cm < 1.8
     sf := 128;
else if cm >= 1.8 and cm < 2.5
     sf := 64;
else if cm >= 2.5 and cm < 3.7
     sf := 32;
else if cm >= 3.7 and cm < 5.5
     sf := 16;
else if cm >= 5.5 and cm < 8.6
     sf := 8;
else if cm > 8.6
     sf := 4;
end if
```

The above structure has shown reasonable performance in the accomplished simulations. It is noted that the above decision limits are only tentative. In addition, the above illustrated number of data transmission rate classes is only one example of the possible number of classes. Different limit values can be used in different embodiments, and the number of data transmission rate classes can be freely chosen for different implementations.

It is also noted that even though in a preferred embodiment the number of the data rate classes corresponds the number of the possible transmitter data rates, the number of the classes does not necessarily need to correspond the number of the different possible transmitter data rates. For instance, a lower number of classes can be used such that two or several of the lower transmitter data rates are included in one data rate class, thereby simplifying the classification procedure and avoiding possible problems caused by the occasionally interleaving distributions of the variables for the lower data rates. In addition, instead of using the actual data rates, the data rate classes can also be denoted as, for example, low, relatively low, medium, relatively high, and high and such that some or all of the classes include more than one transmitter data rate.

The accomplished simulations proved that the above embodiment does not seem to suffer from the low signal-to-noise ratios, as is the case in the prior art power-based method discussed earlier in this specification. The simulations were done with the E_s/N_0 = 10 dB, where the power-based method failed to detect any data rates of the received transmission. At this E_s/N_0 magnitude the above described embodiment, however, achieved the following probabilities of correct data rate

detection (the simulation was accomplished for 10000 radio frames):

Transmitter data rate [kbps]	Probability of correct data rate detection [%]
32	46.85
64	92.25
128	100
256	100
512	100
1024	100

When compared to the described prior art methods based on the CRC decoding and the metrics of the Viterbi decoding, the above embodiment has an advantage in that the data rate estimation is not delayed to after the decoding process. Therefore the embodiment is more suitable to e.g. different Interference Cancellation methods in the receiver that the prior art proposals. Moreover, the above described method is less complex than the methods based on CRC or Viterbi decoding of the data.

As can be seen from Figure 5 and the above table, the described embodiment may not reliably separate in all occasions the lowest data rates of 32 and 64 kbps from each other. This is due the fact that every higher data rate is an integer multiple of two of a lower data rate, the data rates 32 and 64 kbps being relatively close to one another. Because of that, the distributions of the decision variable (*CM*) may overlap. If the incorporation of the lower data rates into one class is not desired and a better performance in the separation of the lowest data rates is required (at the cost of the separation of the higher data rates), the sampling rate of the receiver could be decreased, for example, by

increasing the spreading factor from 4 to 16 in the receiver. If the length of the Fourier transform is kept the same (e.g. 64), this would lead to decrease in the critical Nyquist frequency f_c, thus improving the frequency resolution at the lower frequencies while at the same time narrowing the window of the detectable frequencies. It is to be noted that this process may in some occasions lead to heavy aliasing to the frequencies higher than f_c, if they are still present in the system (i.e. there is a probability that e.g. 1024 kbps might still be used in the transmitter). This aliasing effect, however, can be readily reduced by using low-pass filtering to the received signal prior to the data rate detection.

Although the invention has been described in the context of a CDMA based system, it will be appreciated that similar principles can be applied in other communication systems, for example in a TDMA system or in any telecommunications device receiving data at variable rates and requiring information of the data transmission rate, such as in modems.

While the invention has been described above in connection with the blind data rate detection, the described data rate estimation method could be used together with rate information bits or similar data rate information in order to produce verified and/or corrected data rate estimate. In this case a connection is to be provided between rate estimator unit 40 and channel estimation unit 37 or similar unit of the circuitry accomplishing the verification/correction. This is a viable alternative especially in implementations having high requirements for the accuracy of the transmission rate estimation.

It is also noted herein that while the above describes exemplifying embodiments of the invention, there are several

variations and modifications which may be made to the disclosed solution without departing from the scope of the present invention as defined in the appended claims.

CLAIMS

1. A method for estimating data transmission rate in a communication system with variable data transmission rates wherein a transmission signal includes a plurality of data symbols over a sequence of data frames, comprising:

classifying a data frame of a received transmission signal in accordance with a predefined classification of the data transmission rates; and

estimating the data transmission rate of the received data frame on basis of said classification.

2. A method according to claim 1, wherein the classification is based on frequency content of the received transmission signal.

3. A method according to claim 1 or 2, wherein the classification is based on a power spectral density function estimate of the received transmission signal.

4. A method according to claim 3, wherein the power spectral density function estimate of the received transmission signal is calculated using a Fast Fourier Transform algorithm and coherent averaging of the data symbol sequence of the received transmission signal.

5. A method according to claim 4, wherein a modified Fast Fourier Transform algorithm is used, said modified Fast Fourier Transform algorithm taking predefined symmetries of the transmitted data symbols into account.

6. A method according to any of claims 3 to 5, wherein the estimation of the power spectral density function comprises the steps of:

dividing the total number of received data symbols into blocks, wherein each block includes a predefined amount of consecutive points of the signal;

calculating an individual Fourier Transform for each of said blocks for receiving squared real and imaginary points for each frequency of the signal;

calculating an individual power spectral function estimate for each of the blocks by summing the squared real and imaginary points; and

calculating the power spectral density function estimate by averaging the individual power spectral function estimates.

7. A method according to any of claims 3 to 6, wherein the power spectral density function estimate is normalised by summing the elements of the power spectral density function for obtaining a sum of the elements and by dividing each of said elements by the sum.

8. A method according to any of the preceding claims, wherein the classification further comprises a step of removing effects of noise.

9. A method according to claim 8 when taken together with any of claims 3 to 6, wherein the noise removal comprises subtracting an inverse of the number of elements of the power spectral density function from the power spectral density function.

10. A method according to any of claims 3 to 9, wherein the classification comprises further:

calculating a variable from the power spectral density function for characterising the frequency content of the power spectral density function; and

comparing the variable against limit values of a classification decision structure.

11. A method according to claim 10, wherein the variable characterising the frequency content of the received transmission signal comprises center-of-moment of the power spectral density function.

12. A method according to claim 10 or 11, wherein the magnitude of the variable indicates the relative amount of high frequencies present in the power spectral density function.

13. A method according to any preceding claims, wherein the communication system comprises a cellular code division multiple access communications network, and the data is transmitted between a mobile station and a base station of the network over a radio interface.

14. A method according to any preceding claims, wherein the number of data transmission rate classes of the predefined classification equals the number of the possible data transmission rates.

15. A method according to any of claims 1 to 13, wherein the number of data transmission rate classes of the predefined classification is lower than the number of the possible data transmission rates.

16. A method for channel estimation in a cellular code division multiple access communication system wherein the data transmission rate is estimated in accordance with any of claims 1 to 15.

17. A method according to claim 16, wherein the estimate of the data transmission rate is used to assist in rate selection for Viterbi decoding of the received data symbols.

18. A method according to claim 16 or 17, wherein a data rate information received from a transmitting station and the estimated data transmission rate are both used for the channel estimation.

19. Signal receiving circuitry for use in a communication system with variable data transmission rates wherein data is transmitted as a plurality of data symbols over a sequence of data frames, the signal receiving circuitry comprising a rate estimation unit for receiving an incoming transmission signal, for classifying a data frame of the signal in accordance with a predefined classification of the data transmission rates, and for determining from the results of the classification an estimate of the data transmission rate of the received data frame.

20. Signal receiving circuitry according to claim 19, wherein the rate estimation unit estimates the data transmission rate based on the frequency content of the received signal.

21. Signal receiving circuitry according to claim 19 or 20, wherein the rate estimation unit is arranged to classify the received signal based on a power spectral density function estimate of the received transmission signal.

22. Signal receiving circuitry according to any of claims 19 to 21, comprising a channel estimation unit which utilises the estimated data transmission rate of the received signal in channel estimation.

23. A mobile station including signal receiving circuitry according to any of claims 19 to 22.

24. A base station including signal receiving circuitry according to any of claims 19 to 22.

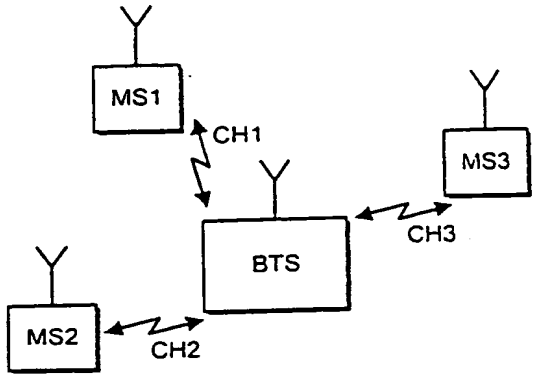
MS1
CH1
MS3
CH3
BTS
MS2
CH2

Fig. 1

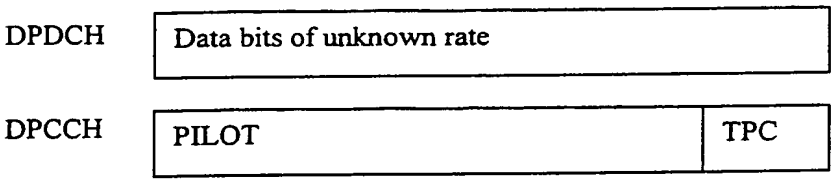
DPDCH
Data bits of unknown rate
DPCCH
PILOT
TPC

Fig. 3

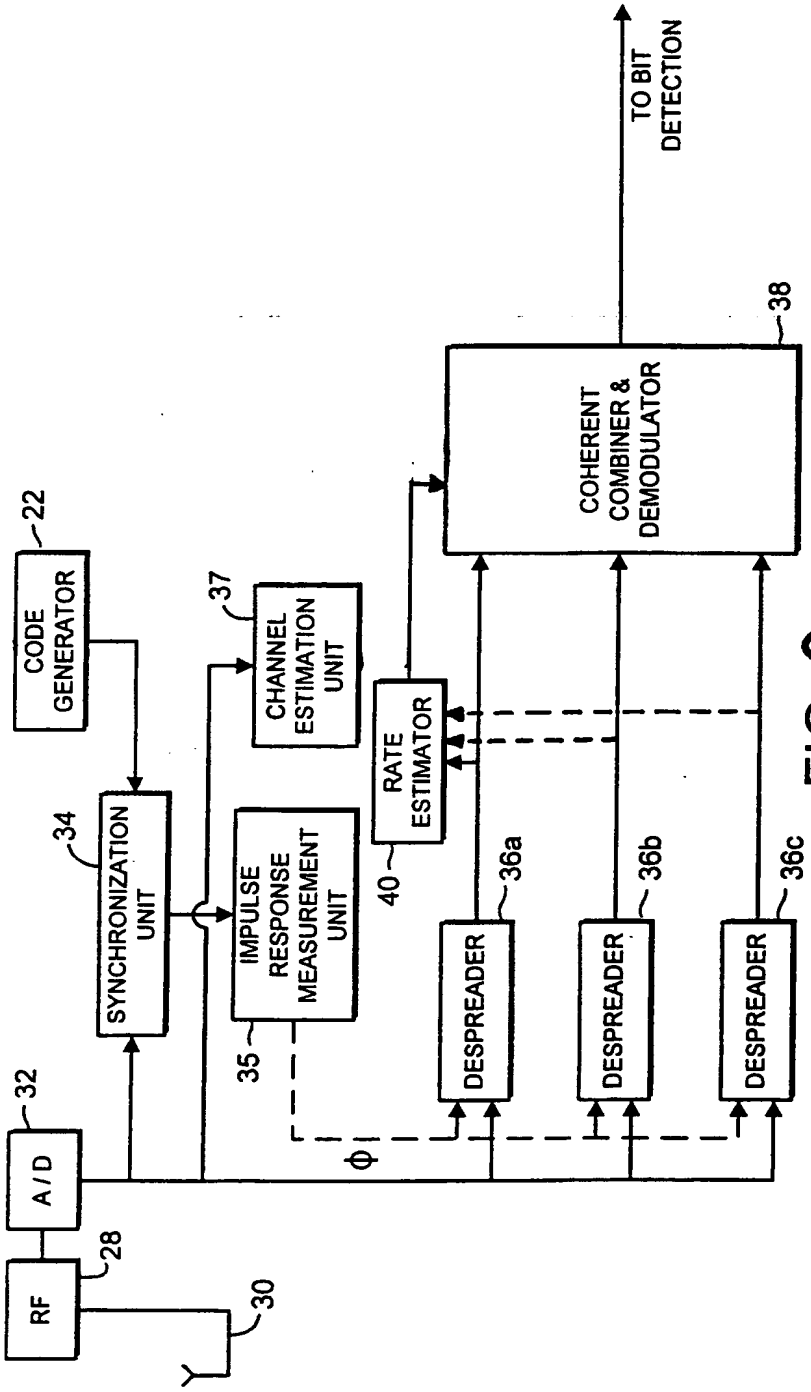
TO BIT DETECTION
38
COHERENT COMBINER & DEMODULATOR
22
CODE GENERATOR
37
CHANNEL ESTIMATION UNIT
RATE ESTIMATOR
40
34
SYNCHRONIZATION UNIT
IMPULSE RESPONSE MEASUREMENT UNIT
35
DESPREADER
36a
DESPREADER
36b
DESPREADER
36c
32
A/D
28
RF
30
Φ

FIG. 2

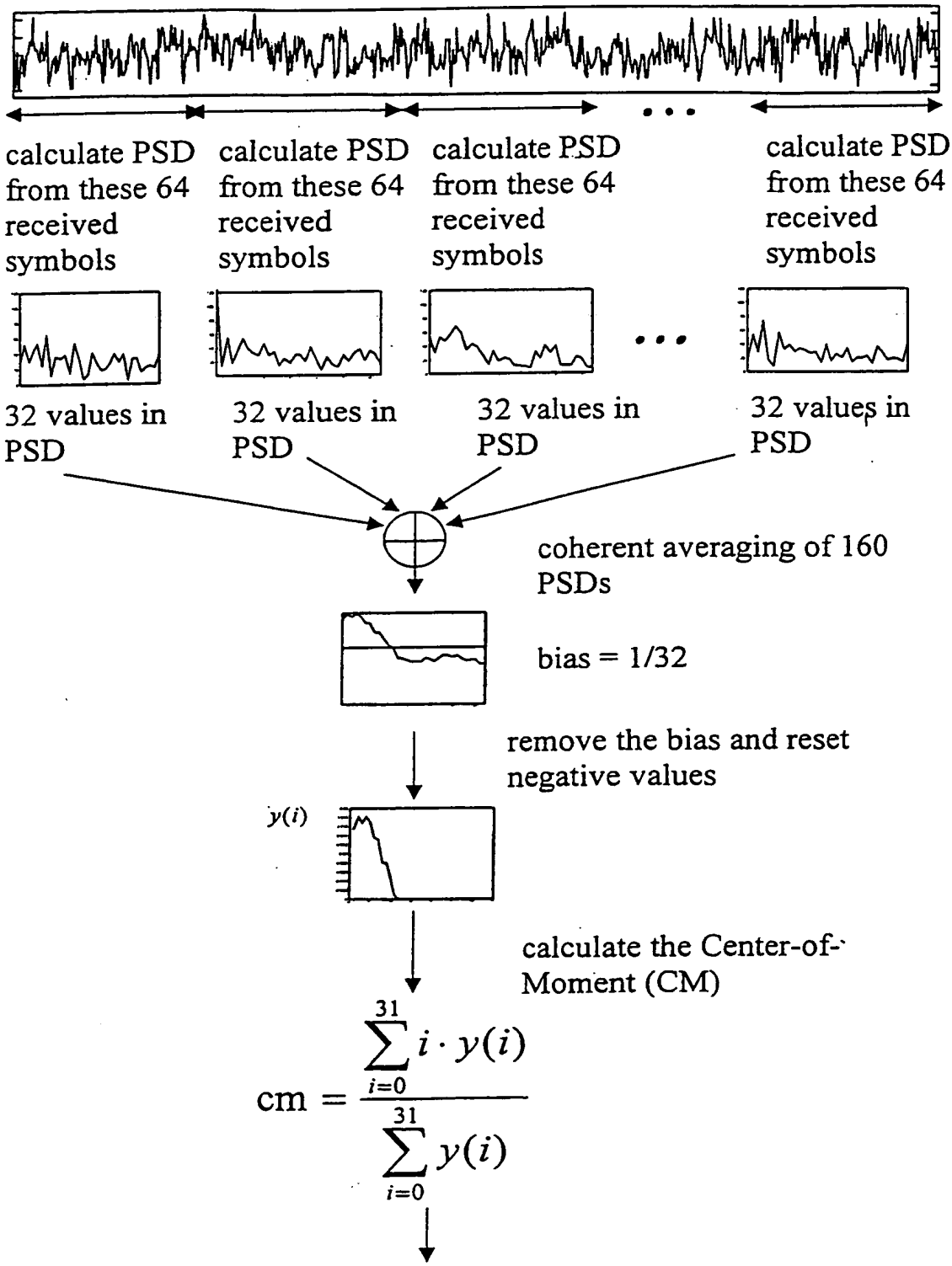
calculate PSD from these 64 received symbols
calculate PSD from these 64 received symbols
calculate PSD from these 64 received symbols
calculate PSD from these 64 received symbols
32 values in PSD
32 values in PSD
32 values in PSD
32 values in PSD
coherent averaging of 160 PSDs
bias = 1/32
remove the bias and reset negative values
y(i)
calculate the Center-of-Moment (CM)
$cm = \frac{\sum_{i=0}^{31} i \cdot y(i)}{\sum_{i=0}^{31} y(i)}$
decide transmission bit rate based on cm

Fig. 4

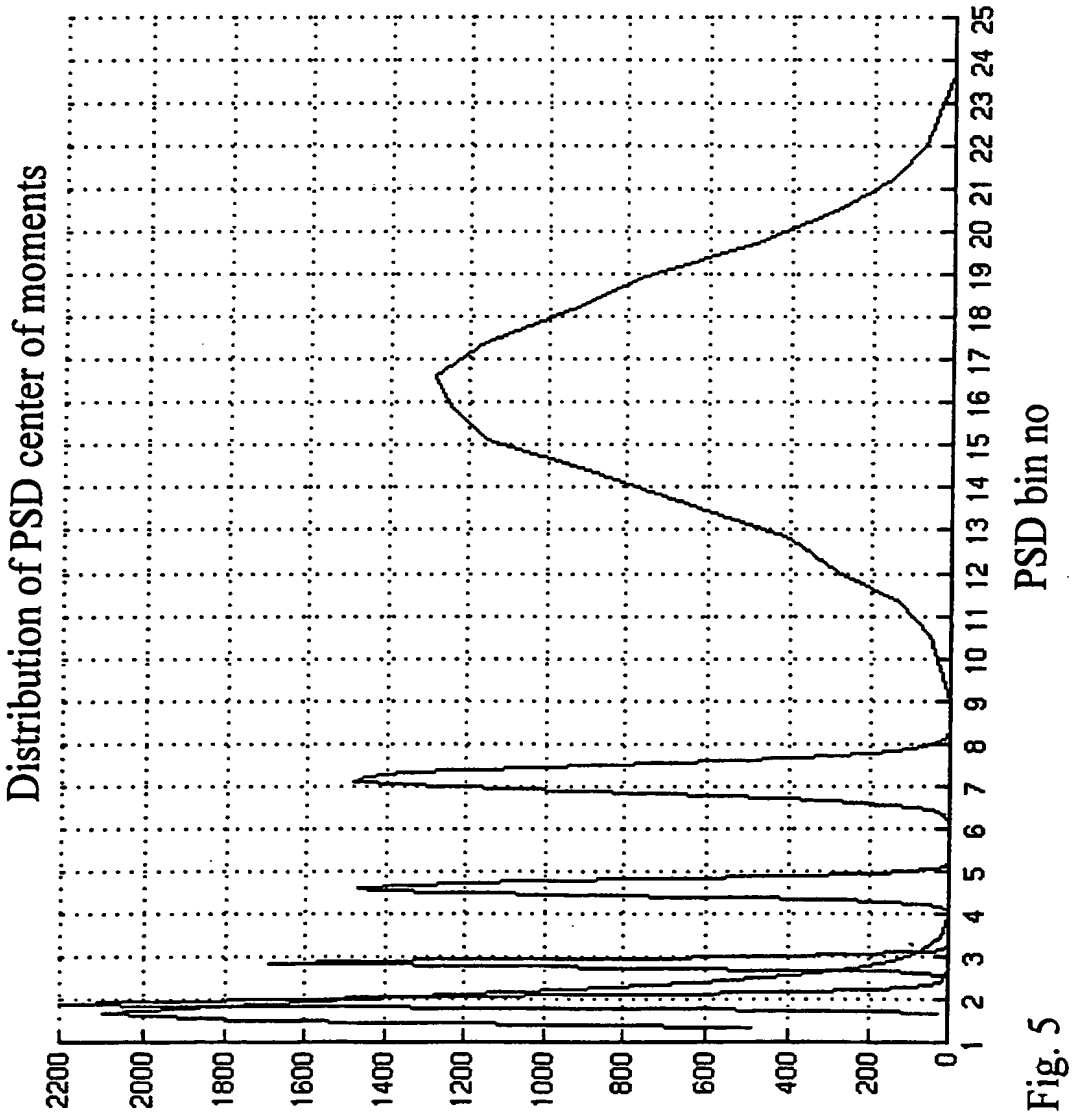
Distribution of PSD center of moments
2200
2000
1800
1600
1400
1200
1000
800
600
400
200
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25
PSD bin no

Fig. 5

INTERNATIONAL SEARCH REPORT

International Application No
PCT/EP 99/06719

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 H04L25/02

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 H04L

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	GB 2 301 999 A (OKI ELECTRIC) 18 December 1996 (1996-12-18) page 3, paragraph 2 page 8, paragraph 2 page 13, paragraph 1 page 13, paragraph 3 — -/—	1-3, 7-10, 12-24

[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
12 May 2000	19/05/2000

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL – 2280 HV Rijswijk Tel. (+31–70) 340–2040, Tx. 31 651 epo nl, Fax: (+31–70) 340–3016	Scriven, P

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PATENT COOPERATION TREATY

PCT

INTERNATIONAL SEARCH REPORT

(PCT Article 18 and Rules 43 and 44)

Applicant's or agent's file reference	FOR FURTHER ACTION see Notification of Transmittal of International Search Report (Form PCT/ISA/220) as well as, where applicable, item 5 below.	
91727/JPR		
International application No.	International filing date *(day/month/year)*	(Earliest) Priority Date *(day/month/year)*
PCT/EP 99/06719	09/09/1999	
Applicant		
NOKIA NETWORKS OY		

This International Search Report has been prepared by this International Searching Authority and is transmitted to the applicant according to Article 18. A copy is being transmitted to the International Bureau.

This International Search Report consists of a total of 3 sheets.

[X] It is also accompanied by a copy of each prior art document cited in this report.

1. **Basis of the report**

   a. With regard to the **language**, the international search was carried out on the basis of the international application in the language in which it was filed, unless otherwise indicated under this item.

   [ ] the international search was carried out on the basis of a translation of the international application furnished to this Authority (Rule 23.1(b)).

   b. With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application, the international search was carried out on the basis of the sequence listing :

   [ ] contained in the international application in written form.

   [ ] filed together with the international application in computer readable form.

   [ ] furnished subsequently to this Authority in written form.

   [ ] furnished subsequently to this Authority in computer readble form.

   [ ] the statement that the subsequently furnished written sequence listing does not go beyond the disclosure in the international application as filed has been furnished.

   [ ] the statement that the information recorded in computer readable form is identical to the written sequence listing has been furnished

2. [ ] **Certain claims were found unsearchable** (See Box I).

3. [ ] **Unity of invention is lacking** (see Box II).

4. With regard to the **title**,

   [ ] the text is approved as submitted by the applicant.

   [X] the text has been established by this Authority to read as follows:

   DETERMINATION OF DATA RATE, BASED ON POWER SPECTRAL DENSITY ESTIMATES

5. With regard to the **abstract**,

   [X] the text is approved as submitted by the applicant.

   [ ] the text has been established, according to Rule 38.2(b), by this Authority as it appears in Box III. The applicant may, within one month from the date of mailing of this international search report, submit comments to this Authority.

6. The figure of the drawings to be published with the abstract is Figure No. 4

   [ ] as suggested by the applicant.

   [ ] because the applicant failed to suggest a figure.

   [X] because this figure better characterizes the invention.

   [ ] None of the figures.

INTERNATIONAL SEARCH REPORT

International Application No
PCT/EP 99/06719

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 H04L25/02

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 H04L

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	GB 2 301 999 A (OKI ELECTRIC) 18 December 1996 (1996-12-18) page 3, paragraph 2 page 8, paragraph 2 page 13, paragraph 1 page 13, paragraph 3 --- -/--	1-3, 7-10, 12-24

[X] Further documents are listed in the continuation of box C.

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"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

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Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL – 2280 HV Rijswijk Tel. (+31–70) 340–2040, Tx. 31 651 epo nl, Fax: (+31–70) 340–3016	Scriven, P

1

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C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication,where appropriate, of the relevant passages	Relevant to claim No.
X	SEOK HO KIM, SCHOLZ: "An optimum generalized cross-spectrum symbol-rate detector" IEEE TRANSACTIONS ON COMMUNICATIONS, vol. 41, no. 9, September 1993 (1993-09), pages 1399-1411, XP000396699 NEW YORK, US ISSN: 0090-6778 page 1399, right-hand column, paragraph 1 page 1399, right-hand column, paragraph 4 -page 1400, left-hand column, paragraph 1	1-3,8-24
X	LEE ET AL.: "On a timing recovery technique for a variable symbol rate signal" IEEE VEHICULAR TECHNOLOGY CONFERENCE, 4 - 7 May 1997, pages 1724-1728, XP000738658 New York, US ISBN: 0-7803-3660-7 page 1724, right-hand column, paragraph 2 figure 5	1-3,7,8, 10,12-24
X	US 4 887 280 A (REISENFELD) 12 December 1989 (1989-12-12) column 1, line 45 - line 51 column 4, line 21 - line 40	1-3,7,8, 10,12-24
E	EP 0 944 212 A (MATSUSHITA GRAPHIC COMMUNICATION SYSTEMS) 22 September 1999 (1999-09-22) figure 4	1-3,7,8, 10,12-24

INTERNATIONAL SEARCH REPORT

Information on patent family members

Inter... nal Application No
PCT/EP 99/06719

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
GB 2301999 A	18-12-1996	CA 2183938 A	24-02-1997
		HK 1001939 A	17-07-1998
		JP 9172428 A	30-06-1997
		US 5978428 A	02-11-1999
US 4887280 A	12-12-1989	NONE	
EP 0944212 A	22-09-1999	JP 11261785 A	24-09-1999